IEA Wind Task 26 Expert Survey

Introductory Webinar
October 21, 2015

Recording and presentation will be available at:
https://emp.lbl.gov/iea-wind-expert-survey-co

Contact us at: ieawind@lbl.gov

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Webinar Logistics

- 30 minute presentation, then open Q&A
- Participants will be on mute during the actual presentation
- Comments/questions can be submitted via “chat” feature
- After the presentation, we will also open the phone lines for verbal Q&A
  - To ask your questions verbally, dial in and mute your computer audio:
    - US/Canada : (866) 612-9922
    - Other countries: (530) 379-4711 – incurs international calling fees for you
    - **Conference ID**: 57 68 48 72
- Recording of webinar and presentation will be available at: https://emp.lbl.gov/iea-wind-expert-survey-co

Presentation Overview

- Who is implementing the survey
- Goals of expert elicitation survey
- What we are asking you to do
  - Five types of questions
  - Key definitions and assumptions
- Survey demonstration
- Logistics and schedule

The survey is voluntary and your individual responses are anonymous

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The purposes of this webinar are:

- To introduce you to the survey, the survey team, and the goals of our study
- To provide some additional background that you may find helpful as you answer questions in the survey – in particular to highlights a few definitions and assumptions
- To provide a brief introduction to the survey software itself
- And to give you an opportunity to ask any questions you may have at this point in the process

Please remember that the survey is voluntary. If you choose to participate (and we hope that you do), you will be listed / acknowledged as a participating expert in the project report, but your individual responses will be kept anonymous. No responses will be attributed to any individual.

Who Is Implementing the Survey

- Lawrence Berkeley National Lab
  - Dr. Ryan Wiser
  - Joachim Seel
- National Renewable Energy Lab
  - Dr. Maureen Hand
  - Eric Lantz
  - Aaron Smith
- Survey Experts
  - Dr. Karen Jenni
  - Dr. Erin Baker

Contact us at: ieawind@lbl.gov

Thanks to the U.S. Department of Energy, Wind and Water Power Program, for making this effort possible

- Other IEA Wind Task 26 Members, including:
  - Denmark (DTU, Ea Energy Analyses)
    - Aisma Vitina, Klaus Skytte
  - Germany (Deutsche WindGuard, Fraunhofer Institute)
    - Silke Luers, Volker Berkhout
  - Ireland (Dublin Institute of Technology)
    - Aidan Duffy
  - Netherlands (EcoFys, TKI Wind)
    - Bob Meijer, Bob Prinsen
  - Norway (NVE, SINTEF)
    - David Weir, Leif Husabo, Iver Bakken Sperstad
  - United Kingdom (Offshore Catapult)
    - Gavin Smart
  - European Commission (Joint Research Centre)
    - Roberto Lacal Arantegui

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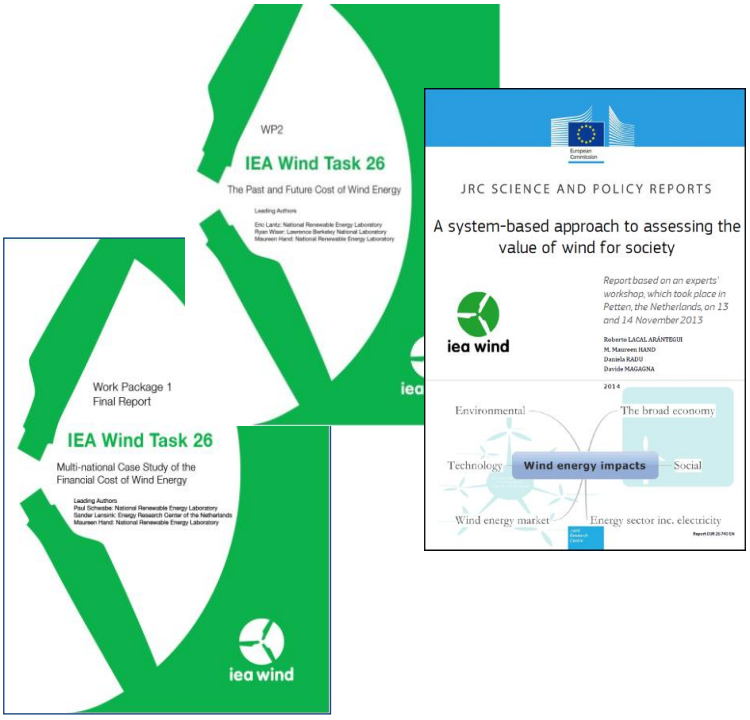
This survey is being implemented by the Lawrence Berkeley National Laboratory and the National Renewable Energy Laboratory, in collaboration with IEA Wind and its member countries, and particularly the IEA Wind Task 26 Members. It is being advised by two survey design and implementation experts.

Cost of Wind Energy Task 26

IEA Wind Task 26 Objective: Provide information on cost of wind energy to understand past, present, and anticipated future trends using consistent, transparent methodologies as well as understand how wind technology compares to other generation options in the broader electric sector.

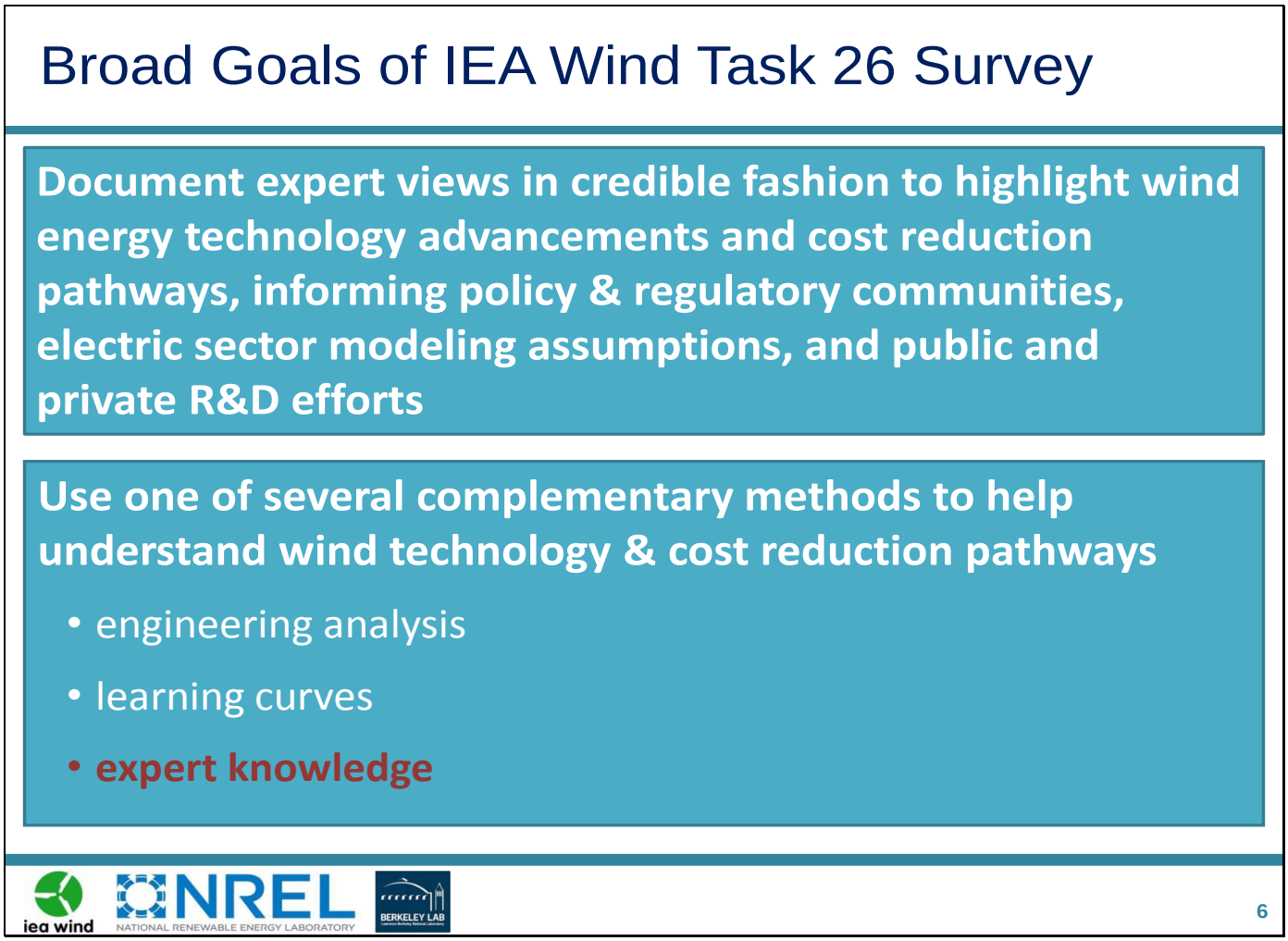
- Comparing land-based wind cost of energy among participating countries
- Exploring cost of offshore wind energy and drivers
- Investigating value of wind energy
- Studying historic and potential future trends for cost of wind energy

Mission of IEA Wind: "…to stimulate co-operation on wind energy research and development and to provide **high quality information and analysis to member governments** and commercial **sector leaders** by addressing **technology development** and deployment and its **benefits, markets, and policy instruments**." – IEA Wind Strategic Plan



The International Energy Agency (IEA)'s Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems was founded in 1974, and sponsors cooperative research tasks among its 20 Member Countries and others. Among the numerous areas of work is Task 26 on the Cost of Wind Energy, the participants of which include: Denmark (DTU, Ea Energy Analyses), Germany (Deutsche WindGuard, Fraunhofer Institute), Ireland (Dublin Institute of Technology), Netherlands (EcoFys, TKI Wind), Norway (NVE, SINTEF), United Kingdom (Offshore Catapult), United States (NREL and LBNL), and the European Commission (Joint Research Centre).

IEA Wind Task 26 is working to understand the current state and cost of wind energy technologies, and how costs might evolve in the future. **This survey of top experts in the field is intended to further these efforts.**



A key question is *how* one can develop reasonable estimates of how well a set of technologies, not yet fully mature and at different levels of development, will perform in the future—especially given uncertainty about different alternative futures scenarios, different technology and market evolution pathways, and so on.

Careful assessment of cost projections from relevant wind energy experts (the approach being used here) is only one of several methods that can be used to increase our understanding of future technology and cost trends. Other approaches include: (1) Use past data and trends for wind energy costs, projected into the future; (2) Develop "learning models" based on experience in related fields and calibrate them with wind energy data; and (3) Conduct scientific and engineering analysis to identify opportunities.

When there is no "objective" source for estimates of the quantities of interest, a common approach to developing those estimates is to use formal "expert elicitation" – an approach where we ask people who know the most about the current state of the technology where they think those technologies will go in the future (and, potentially, how changes in policy or other factors might affect the evolution of the technology and associated markets). While formal expert elicitations are typically conducted through tailored individual interviews, the goals of this study are somewhat broader than the usual study – so we have combined some aspects of expert elicitation with more general questions about cost drivers and the relative impact of different technology advances on costs.

Specific Goals of Survey

Conduct online survey of wind energy experts to gain insight on:

- level of possible wind technology advancement and cost changes in the near- and long-term
- areas within which advancements and cost reductions are potentially most sizable
- broad drivers most likely to facilitate wind technology advancements and cost reductions

Compare insights for onshore (land-based), fixed-bottom offshore and floating offshore wind, and compare views among: a) European & U.S. responses; b) industry & public sector R&D responses; c) survey responses to broader literature review

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The most detailed and technical questions in the survey are questions about the changes in costs of wind energy in the future. Here we are interested in your assessment of the costs of wind energy in the future (in 2020, 2030, and 2050). Many different factors affect costs, including technical, market, and project-specific factors, as well as policies. As all of these factors are uncertain, so, of course are the future costs of wind energy – thus the survey does NOT ask you to provide a single estimate of future costs, but rather asks about the range you think is likely to encompass the future costs. We'll talk a little bit more precisely about what that means a little later in the presentation, and there is a detailed discussion in the survey itself.

In addition to the cost-focused questions, we have questions asking you to rank broad drivers in terms of how much you think they will contribute to achieving lower wind energy costs in the future, and some other questions asking about how much you think specific advancements will contribute to reducing costs.

We are soliciting input from a diverse set of experts, and about three wind application areas (as shown on the slide); results will allow us to compare insights across the application, and across and between different "types" of experts (e.g., based on geographic areas of expertise, technical areas of expertise, industry/research perspectives, etc.).

Targeted Respondents

Casting a Wide Net

- unlike many expert elicitations, we seek relatively wide distribution with larger number of experts invited to participate

Ideal Respondent

- strategic, system-level thought-leaders, with wind technology, cost, and/or market expertise

Respondent Type

- industry, R&D institutions, academia, others

Technology Specialization

- onshore and offshore (fixed and floating)

Geography

- primarily Europe and U.S., but do not foreclose other regions

We welcome your suggestions for additional experts who should be asked to participate. Email ieawind@lbl.gov at any time during this process.

What We Are Asking

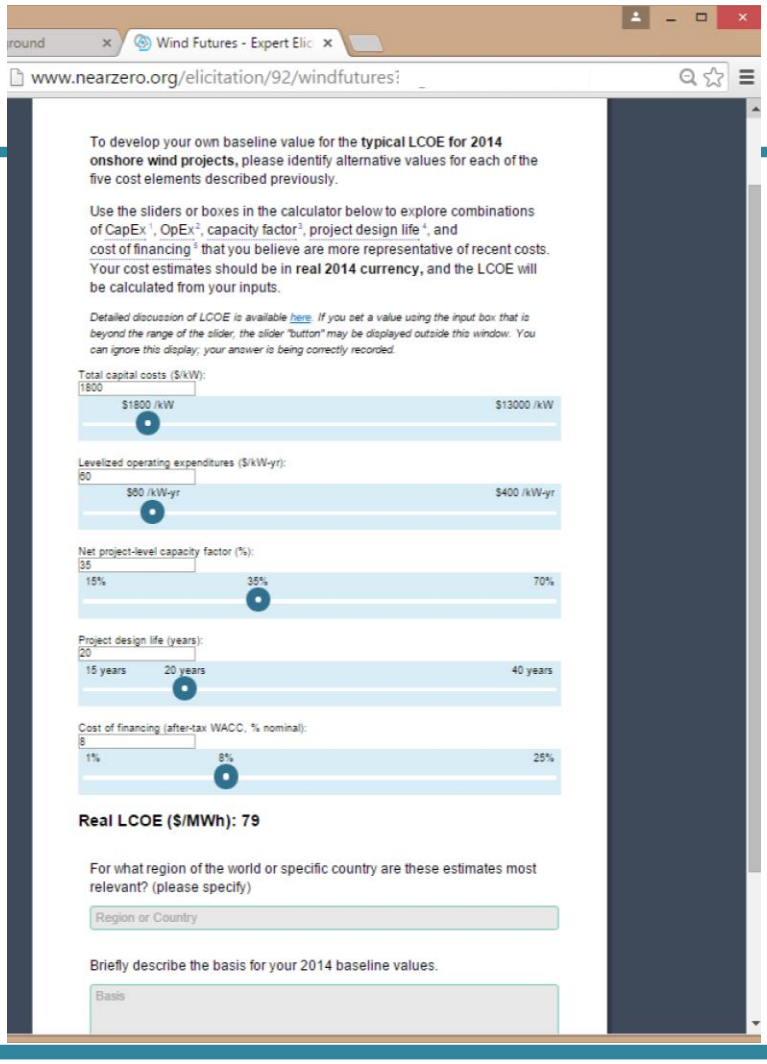
- Respondent “demographics” to allow comparisons across respondent groups, and questions to allow survey branching
  - Wind application type [onshore, fixed-bottom offshore, floating offshore]
  - Currency selection [USD, Euro– average 2014 exchange rates]
- Your estimate of the levelized cost of electricity (LCOE) for wind energy
  - Baseline 2014 values and future year estimates (2030, 2020-50)
  - Built up from five key cost elements
  - Including your uncertainty about future costs (low, high, median)
- Your ranking of several potential broad drivers of cost reductions
  - Importance in achieving lower future costs
- Your expectations for how turbine characteristics may change by 2030
- Your ratings of a detailed list of potential advancements by 2030
  - Expected impact on reducing costs

Introduction to LCOE and Its Components

- **LCOE** = The cost per unit energy of generating electricity from a specific source over an assumed project design life that allows recovery of all project expenses and meets investor return expectations. **Real 2014 currency.**
  - **Total capital costs (CapEx).** Includes all up-front costs to the plant boundary and excludes all costs beyond the plant boundary. As defined in this survey, CapEx includes any electrical cabling within the plant, but excludes any needed substations, transmission lines, or grid interconnection costs. For offshore wind, within-plant array cabling is included, but CapEx excludes the offshore substation, any HVDC collector stations and associated cables, and costs for grid connection to land.
  - **Levelized operating expenditures (OpEx).** Represents an annualized estimate of total operating costs over the project design life, including maintenance and all other ongoing costs (e.g., insurance, land payments, etc.). As defined in this survey, OpEx excludes any costs associated with grid interconnection, substations, or transmission usage.
  - **Net project-level capacity factor.** Annual average energy output relative to the potential output if the project operated at its maximum capacity for a full year.
  - **Project design life.** The design life of a project considered by investors when deciding whether to finance a project.
  - **Cost of financing (after-tax nominal WACC).** The after-tax, nominal weighted average cost of capital (WACC) represents the average return required by the combination of equity and debt investors to make a project an attractive investment opportunity.
- **Note:** survey assumes 25% corporate tax rate, 20-year straight line depreciation, 2% inflation rate.

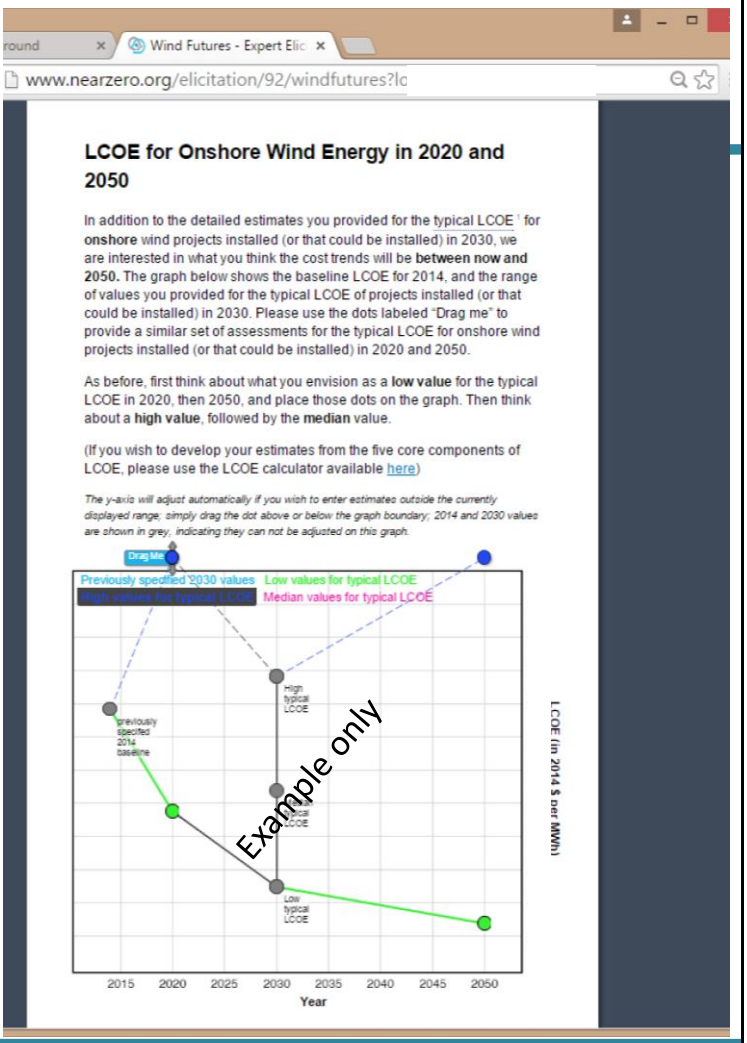
For 2014 Baseline and for 2030, LCOE Estimates Are Built Up from the Five Components

- Please **do** consider possible changes in wind energy
  - Technologies
  - Markets
  - Policies
- Please **assume no changes** in:
  - Macroeconomic conditions
  - Materials and commodity prices
  - Other factors not directly related to the wind energy business



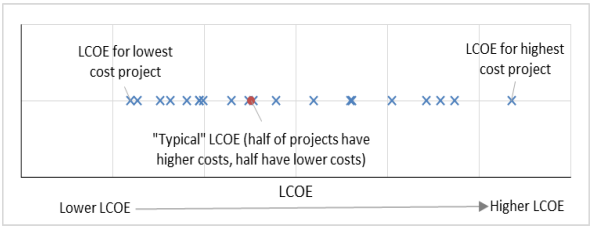
For 2020 and 2050, You Will Estimate the LCOE Directly Using an Interactive Graph

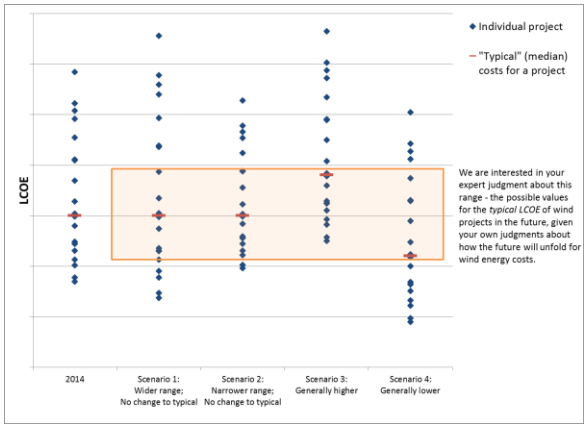
- Your 2014 Baseline LCOE and your low, median, and high estimates for 2030 are shown initially
- Use the simple “drag and drop” dots to define three potential cost trend curves



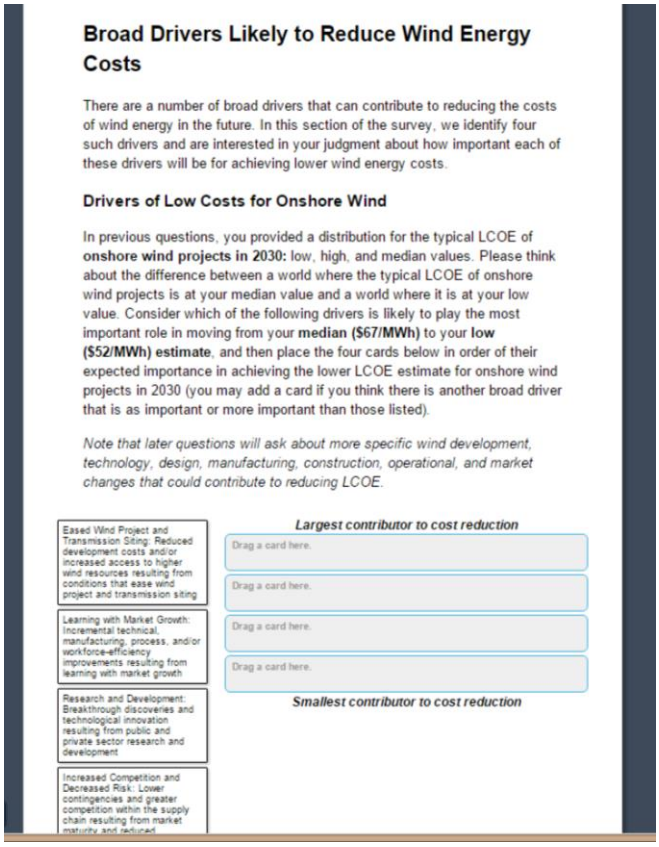
For All Estimates of the Future LCOE of Wind Energy, Our Focus Is On the "Typical" Cost

- LCOE of individual projects span a wide range and are influenced by many factors unrelated to wind energy technologies
- Our focus is on general trends rather than this project-to-project variability
- We use "typical LCOE" to represent the median project cost: half of all projects will have costs lower than the typical LCOE, and half will have costs that are higher
- When asking about the range of future costs, we retain this focus on the range of *typical LCOE*:
  - **Low cost:** value that is sufficiently low that there is only 1 chance in 10 that the typical (or median) LCOE for projects installed will turn out to be lower
  - **High cost:** value that is sufficiently high that there is only 1 chance in 10 that the typical (or median) LCOE for projects installed will turn out to be higher
  - **Median cost:** value where you think that it is equally likely that the typical LCOE in 2030 will be less than or greater than the LCOE that you enter





Ranking of Broad Drivers of Cost Reduction



Broad Drivers Likely to Reduce Wind Energy Costs

There are a number of broad drivers that can contribute to reducing the costs of wind energy in the future. In this section of the survey, we identify four such drivers and are interested in your judgment about how important each of these drivers will be for achieving lower wind energy costs.

Drivers of Low Costs for Onshore Wind

In previous questions, you provided a distribution for the typical LCOE of **onshore wind projects in 2030:** low, high, and median values. Please think about the difference between a world where the typical LCOE of onshore wind projects is at your median value and a world where it is at your low value. Consider which of the following drivers is likely to play the most important role in moving from your **median ($67/MWh)** to your **low ($52/MWh) estimate**, and then place the four cards below in order of their expected importance in achieving the lower LCOE estimate for onshore wind projects in 2030 (you may add a card if you think there is another broad driver that is as important or more important than those listed).

Note that later questions will ask about more specific wind development, technology, design, manufacturing, construction, operational, and market changes that could contribute to reducing LCOE.

Eased Wind Project and Transmission Siting: Reduced development costs and/or increased access to higher wind resources resulting from conditions that ease wind project and transmission siting

Learning with Market Growth: Incremental technical, manufacturing, process, and/or workforce-efficiency improvements resulting from learning with market growth

Research and Development: Breakthrough discoveries and technological innovation resulting from public and private sector research and development

Increased Competition and Decreased Risk: Lower contingencies and greater competition within the supply chain resulting from market maturity and reduced

Largest contributor to cost reduction

Drag a card here.

Drag a card here.

Drag a card here.

Drag a card here.

Smallest contributor to cost reduction

- We have identified four broad potential drivers of cost reduction
- You can add your own drivers to this list
- You will be asked to rank these drivers through a “card sort”
- Please think about the difference between two hypothetical scenarios in 2030: one where the typical LCOE is equal to your median estimate, and one where the typical LCOE is equal to your low estimate
  - How import was each driver in achieving *your low estimate*

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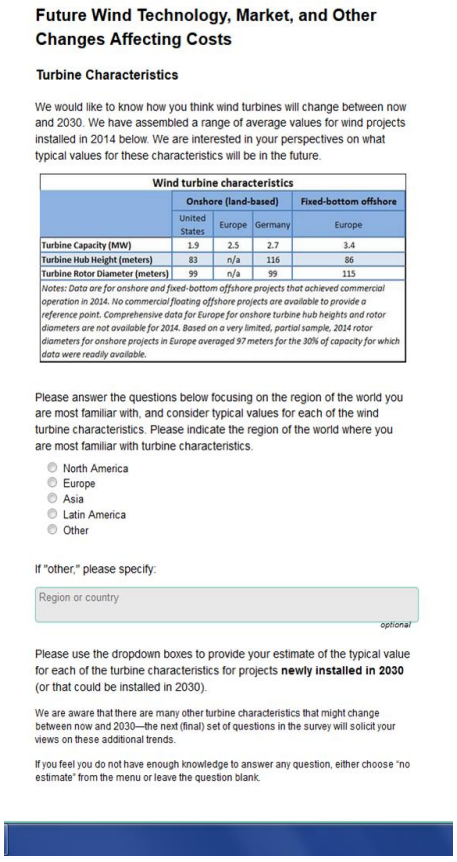
One of the questions potentially of interest to policy-makers is what factors or broad drivers are most likely to lead to *lower* wind energy costs in the future. Typically, “importance” questions are seen as easy to answer, but those answers are very difficult to interpret without a clear question context. So, for this ranking question, we ask you to think specifically about the difference between your median estimate of costs in 2030, and your LOWER estimate of those costs, and then rank the broad drivers in terms of how important they are in reaching that lower estimate.

Turbine Characteristics in 2030



Future Wind Technology, Market, and Other Changes Affecting Costs

Turbine Characteristics

We would like to know how you think wind turbines will change between now and 2030. We have assembled a range of average values for wind projects installed in 2014 below. We are interested in your perspectives on what typical values for these characteristics will be in the future.

Wind turbine characteristics

	Onshore (land-based)			Fixed-bottom offshore
	United States	Europe	Germany	Europe
Turbine Capacity (MW)	1.9	2.5	2.7	3.4
Turbine Hub Height (meters)	83	n/a	116	86
Turbine Rotor Diameter (meters)	99	n/a	99	115

Notes: Data are for onshore and fixed-bottom offshore projects that achieved commercial operation in 2014. No commercial floating offshore projects are available to provide a reference point. Comprehensive data for Europe for onshore turbine hub heights and rotor diameters are not available for 2014. Based on a very limited, partial sample, 2014 rotor diameters for onshore projects in Europe averaged 97 meters for the 30% of capacity for which data were readily available.

Please answer the questions below focusing on the region of the world you are most familiar with, and consider typical values for each of the wind turbine characteristics. Please indicate the region of the world where you are most familiar with turbine characteristics.

- North America
- Europe
- Asia
- Latin America
- Other

If "other," please specify:

Region or country

optional

Please use the dropdown boxes to provide your estimate of the typical value for each of the turbine characteristics for projects **newly installed in 2030** (or that could be installed in 2030).

We are aware that there are many other turbine characteristics that might change between now and 2030—the next (final) set of questions in the survey will solicit your views on these additional trends.

If you feel you do not have enough knowledge to answer any question, either choose "no estimate" from the menu or leave the question blank.

- We ask for your estimates of typical:
  - Turbine capacity (MW)
  - Hub height (meters)
  - Rotor diameter (meters)
- For the region of the world you are most familiar with
- For onshore, fixed-bottom offshore, floating offshore, all in 2030

Expected Impact of Technology and Market Changes

Future Wind Technology, Market and Other Changes Affecting Costs

Listed below are a variety of wind development, technology, design, manufacturing, construction, operational, and market changes that could contribute to reducing the LCOE for wind projects by 2030. Please indicate what you think the contribution of each item will be to reducing costs by 2030.

Specifically, we are interested in your overall judgment about the ***expected impact***[1] of each item on reducing the LCOE for wind projects in the future.

You will see this list of items separately for each wind application area you have previously addressed.

Onshore (Land-based) Wind

Scaling in wind turbines

	No expected impact	Small expected impact	Medium expected impact	Large expected impact	No opinion
Increased turbine capacity and rotor diameter (thereby maintaining specific power[2])					
Increased rotor diameter such that specific power[2] declines					
Increased tower height					

Wind plant design

	No expected impact	Small expected impact	Medium expected impact	Large expected impact	No opinion
Economies of scale through increased project size					
Improved plant-level layout through understanding of complex flow and high-resolution micro-siting					
Large variety of alternative turbine designs to suit					

- Simple rating scale to compare ***expected impact*** of specific potential advances between 2014 and 2030:
  - Scaling in wind turbines
  - Wind plant design
  - Turbine and component design
  - Foundation, support structure, and installation
  - Supply chain manufacturing
  - Operating expenditures and performance
  - Competition, risk, development, and other opportunities
- Asked separately for each wind application

When thinking about these questions, please think about both the likelihood of advances and the impact of those advances if they occur (this is the “expected impact”).

Launching the Survey

- You should have received a ***personalized*** link in your invitation email. It will look something like this:
  - http://www.nearzero.org/elicitation/107/windfutures?login=<your code here>
- That's it! Click the link, or copy and paste it into your browser, to launch the survey

In the webinar (available online), there will be a short demonstration of the survey software if time allows.

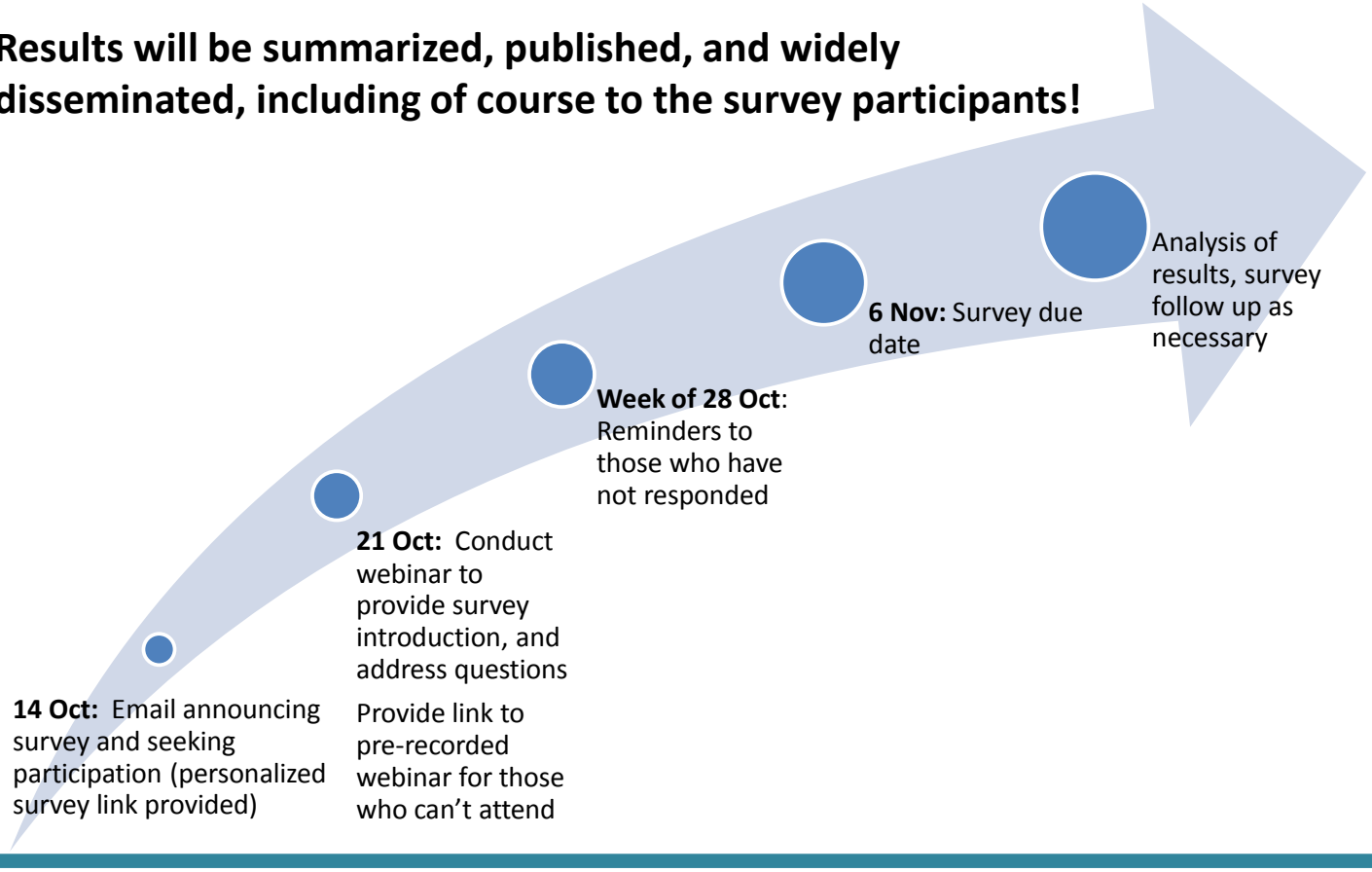
The survey is straightforward and easy to use; previous slides have screen captures of several of the key questions that are being asked. If you have any questions or difficulties with the software, you can check out the demonstration in the recorded webinar, or you can email us at ieawind@lbl.gov and one of the survey team will be happy to get back to you.

Final Survey Logistics

- The survey is voluntary and your individual responses are anonymous: we will identify who participated in the survey, but will not identify any individual response
- We expect it will take most people between 45 and 90 minutes to complete: this is a reasonably involved survey, but we hope it is worth your time
- You do not have to finish the survey in one sitting: answers are saved each time you click “next” to go to the next screen
- There are two options for pausing and returning
  - You can simply leave the survey open in a window and come back to that window later
  - You can close the survey window and use your original link to re-access the survey later
    - If you choose this approach, you will not be able to go back and change your previous responses

Survey Schedule

Results will be summarized, published, and widely disseminated, including of course to the survey participants!



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Thank you very much for your time and your interest in our survey. Answers to the questions asked during the webinar can be listened to in the webinar recording available on https://emp.lbl.gov/iea-wind-expert-survey-co. Should you have any further questions or comments, please do not hesitate to contact us at ieawind@lbl.gov . We hope you participate and look forward to seeing you soon in the survey.